Euphorbia esula: Achieving management objectives: Analysis of 2000 data

Prepared for:

Arrowwood National Wildlife Refuge, Pingree, ND

Tewaukon National Wildlife Refuge, Cayuga, ND

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INTRODUCTION

In spring 2000, we continued to assess the ecological impacts of the invasive non-native species *Euphorbia esula* (leafy spurge) on rangeland and natural areas in the northern Great Plains, and to evaluate the status of biocontrol insects released to reduce spurge populations. In 1998, permanent plots were established to monitor changes in the plant community, biocontrol population levels, and soil nutrient status over time. Overall goals of the study are to quantify the response of biocontrol agents, native and non-native species, and soil nutrient availability to varying management strategies. The primary objectives of the 2000 field study were to:

1) Continue vegetation surveys to describe the composition and relative frequency of plant species on study sites.

2) Determine the density and life-stage distribution of leafy spurge on permanent plots.

3) Measure dry-weight biomass of 5 categories of vegetation (leafy spurge, native and non-native grasses, litter, and forbs).

4) Determine the abundance and distribution of biocontrol insects.

5) Assess initial nutrient status of the soil.

METHODS

Study area

Permanent baseline transects were established in spring 1998 on sites at Arrowwood National Wildlife Refuge (ANWR) and Tewaukon National Wildlife Refuge (TNWR) in the northern mixed grass prairie of North Dakota. At ANWR, four transects are located at Arrowwood West (Grazing Unit 4; T144N R65W E1/3 Sec 24) and two transects are located at Grasshopper Hills (Grazing Unit 26, T143N R64W E1/2 Sec 21). Three baseline transects are located at TNWR (Management Unit 12).

At each site, the baseline transect was extended along the central horizontal axis (length) of the study area (field), forming two rectangular areas of comparable size on either side of the baseline. Permanent study plots were established by stratified random sampling at 10 m intervals along the baseline transect, alternating between the right and left side of the central baseline. The distance between the study plot and the baseline was randomly generated and marked off (paces) perpendicular to the baseline, at each interval. The maximum distance was determined a priori by the approximate width of the study area. Study plots were permanently marked with electric fence post, rebar, and a numbered aluminum tag. The permanent plots consisted of a 0.5 x 2.0 m vegetation plot

for sampling plant species composition and leafy spurge demographics, and an adjacent sweep plot for sampling biocontrol insects (Fig. 1). Because the field sites varied in size, the length of the baseline transect and number of plots sampled at each site varied (Table 1).

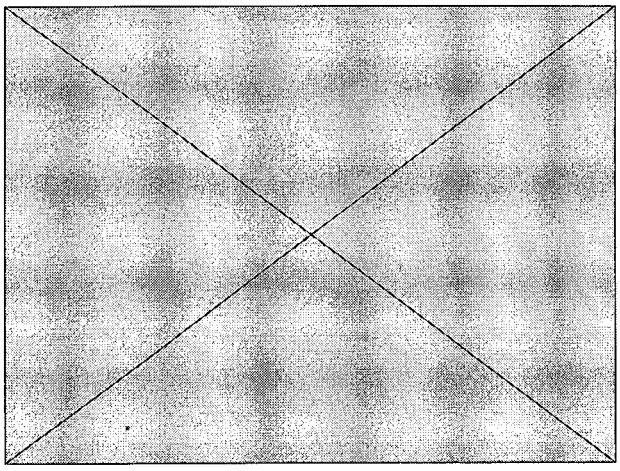


Figure 1. Baseline transect (solid line) with permanent 0.5 x 2.0 m vegetation plots and adjacent insect sweep area.

Table 1. Length of baseline transects (meters) and number of permanent plots sampled at each site.

Site	Baseline length	# of plots
Arrowwood West (AW)		
AW1	310 m	31
AW2	260 m	27

AW3	160 m	16
AW4	400 m	41
		Total = 115
Grasshopper Hills (GH)		
GH1	300 m	31
GH2	450 m	46
		Total = 77
Tewaukon (TE)		
TE1	90 m	9
TE2	220 m	23
TE3	290 m	30
		Total = 62

Plant species composition.

Vegetation plots have been surveyed each year since the study began in 1998 to determine plant species composition, as well as the abundance, trend, and distribution of leafy spurge in the study area. Plots (total area = 1 m^2) consisted of seven nested subunits (Table 2) within the permanent plots, which increased the efficiency of sampling efforts. This also allowed sampling area to be scaled back during analysis to detect trends in more abundant species such as leafy spurge. All plant species present at the time of sampling and the smallest subunit in which they occurred were recorded for each plot.

Table 2. The dimensions of the nested subunits.

Subunit number	Dimensions (cm)
1	6.25 x 12.5
2	12.5 x 25.0
3	12.5 x 50.0
4	25.0 x 50.0
5	25.0 x 100.0
6	50.0 x 100.0
7	50.0 x 200.0

The vegetation data were used to calculate the relative frequency of each species (percentage of plots where a species occurred) for each site (Appendix A).

Leafy spurge density

To assess the density and distribution of spurge, leafy spurge seedlings and stems from the current growing season were counted in each vegetation plot. Due to the abundance of spurge plants on most sites, a smaller area was sampled. Sampling of spurge density was taken in the 12.5 x 50 cm portion of the plot (subunit 3). However, due to the low density of spurge observed in our plots at TNWR, the sampling area was increased to 25 x 50 cm (subunit 4).

Biocontrol insects

Biocontrol insects (*Aphthona* spp.) were sampled during peak adult emergence in late-June/early-July 2000, under ideal environmental conditions (clear afternoons when air temperature > 75 F, wind speed $\leq$ 10 mph, and vegetation is dry). Because the sweep method employed was potentially destructive to vegetation, insect sampling was conducted along five transects adjacent to vegetation plots (Fig. 1). Insects were collected with a 38 cm sweep net, at a rate of five sweeps per transect, counted by species, and released at the collection site. Because populations of flea beetles have reached levels at which total counts are unreliable, we grouped flea beetle abundance into four categories this season. Categories consist of 0 (no flea beetles present), 1 (1-10 flea beetles present), 2 (11-50 flea beetles present), 3 (50-low hundreds of flea beetles present), and 4 (greater than approximately 500 beetles present).

The total aerial cover of *E. esula* in sweep transects and in vegetation plots also was recorded. Percent cover was visually estimated using four cover classes (0 = no spurge present, 1 = 1-25%, 2 = 25-50%, 3 = 50-100%). Previous analyses indicated that over all study sites, the cover of spurge in the vegetation and sweep plots was highly correlated ($r = .82$, $p = 0.0001$, $n = 251$).

RESULTS AND DISCUSSION

Species Composition

Plant species present at Arrowwood and Tewaukon NWR study sites in 2000 and the relative frequency of each are reported in the Appendix. Frequency plots were constructed to describe the plant community composition and to identify the dominant species at each site (Figs. 2-4). Averaged across all sites at Arrowwood West (AW), 19.4% of species observed were introduced. Although native species represent the majority of those found, *Poa pratensis* and *Euphorbia esula* were the dominant species at each site, and *Bromus inermis* ranked as one of the top five species found. The relative frequency of *E. esula* at AW1, AW2, AW3, and AW4 was 70.97%, 69.23%, 75.0%, and 87.5%, respectively. The native woody plants *Rosa arkansana* and *Symphoricarpos occidentalis* were the most prominent native species at all AW sites, and also were among the top five species present (Appendix).

Compared to Arrowwood west, our permanent plots at Grasshopper Hills (GH) had a lower overall percentage of introduced species (17.6%), but *Poa pratensis* and *Euphorbia*

esula are similarly dominant species in the landscape. *P. pratensis* was the most frequent species found at these field sites (83.3% and 100% at GH1 and GH2, respectively), while *E. esula* occupied 75.0% of plots at GH1 and 52.5% of plots at GH2 (Appendix, Fig. 3). *Bromus inermis* was present to a lesser extent than at AW sites (16.7% and 24.4% at GH1 and GH2, respectively), possibly due to the lower available water capacity at Grasshopper Hills. Furthermore, the most frequent native species found at GH1 were *Carex spp.*, *Artemisia ludoviciana*, and *Symphoricarpos occidentalis* (50.0%, 43.3%, and 43.3%, respectively), while those at GH2 included *S. occidentalis, R. arkansana, and Aster ericoides* (75.6%, 44.4%, and 35.6%, respectively).

The community composition of plots at Tewaukon NWR (TE) was also highly variable. Similar to sites at Arrowwood NWR, all field sites at TE were dominated by *P. pratensis* (Appendix; Fig. 4). However, *E. esula* was not as frequent at the TE sites, and was actually absent from our sample plots at TE1. The non-native grass *Agropyron repens* was the second most dominant species at TE1 and TE3 (55.6% and 62.1%, respectively), while occupying a less prominent role at TE2 (36.4%). At TE1, the three most frequently found native species were the grasses *Calamovilfa longifolia* and a *Stipa spp.*, and the forb *Artemisia ludoviciana.* Those at TE2 included a *Carex spp.*, *Equisetum laevigatum*, and *Ambrosia psilostachya*, while at TE3 the most frequent native species were *A. ericoides*, as well as a *Carex spp.* Furthermore, the overall frequency of native species at Tewaukon NWR was 78.1%.

Summary of 2000 field data

To summarize the remainder of our 2000 field season data, we ran a stepwise regression on data from each refuge, to determine the factors best able to predict the change in *E. esula* stem number between 1998 and 2000. We included biomass data, initial leafy spurge stem counts, soil nitrogen, and flea beetle abundance over the three years as possible variables in the model. At AW field sites, significant ($p<0.05$) factors included *Aphthona nigriscutis* density in 1998, 1999, and 2000, *E. esula* stem density in 1998, *A. lacertosa/A. czwalinae* density in 2000, and biomass of non-native grasses. We then ran a regression including these factors as independent variables to obtain the predicted change in *E. esula* stems between 1998 and 2000, and plotted these values against the observed change in *E. esula* stem number between 1998 and 2000 (Fig. 5a.). This analysis indicates that variables in our model account for 58% of the variance in the change in *E. esula* stems between 1998 and 2000. The model is:

Change in *E. esula* stems = -3.88 + 5.75(1998 *A. nigriscutis* density) + 0.08(1999 *A. nigriscutis* density) –23.80(2000 *A. nigriscutis* density) - 1.05(1998 *E. esula* stem density) +14.50(2000 *A. lacertosa* density) – 0.21(biomass of non-native grass).

The factors best able to describe the change in *E. esula* stem density at GH field sites are 1998 E. esula stem density, 2000 A. nigriscutis density, and biomass of litter. We ran a regression including these factors as independent variables to obtain the predicted change in *E. esula* stems between 1998 and 2000; the plot of these values against the actual

change in *E. esula* stem density is illustrated in Fig. 5b. These factors were less effective at predicting change in *E. esula* stem density than those chosen for AW, accounting for only 46% of the variance. The model is:

Change in *E. esula* stems = -2.47 - 0.71(1998 *E. esula* stem density) + 5.55(2000 A. nigriscutis density) + 0.03(biomass of litter).

The factors best able to describe the change in *E. esula* stem density at TE field sites are the densities of *A. lacertosa* and ants during the 2000 field season. We ran a regression including these factors as independent variables to obtain the predicted change in E. esula stem density between 1998 and 2000, and plotted these values against the actual change in *E. esula* stem density (Fig. 6). These factors accounted for less variation, only 34%) in stem counts than those determined for either site at AWNWR. The model is:

Change in *E. esula* stems = 0.52 + 4.45(2000 *A. lacertosa* density) – 6.87(ant density).

By characterizing the field sites in this manner, we can see that the sites not only vary in the amount of leafy spurge infesting them, but also in the factors that may control the level of infestation. These models will help us interpret changes we see after treatment applications this spring, and to understand differences in the effectiveness of our treatments across sites. In particular, the low predictive power of the factors we've measured at TNWR suggest either that at low infestations, variance is too high to allow prediction, or that we have failed to measure some component of the environment that is more influential there than at ANWR.

Plans for 2001 Field Season

Despite the dominance of non-native plants, native vegetation continues to persist at each study site. During the 2001 field season, we will apply our experimental treatments, following prescribed burns at each field site. The experimental treatments include carbon amendment (to lower N available to plants), interseeding of warm-season native grasses, as well as combinations of these treatments. To assist the establishment of our interseeded grasses, we will mow the seeded and half of the control plots once vegetation height is approximately 12 inches (2-3 times during the 2001 field season). The same measurements performed during the 2000 field season will be repeated this season and for two seasons following, to assess any changes in *E. esula* density, vegetation composition, vegetation biomass, soil N availability, and biocontrol abundance that occur in response to the prescribed burn and experimental treatments. We are optimistic that a feasible management strategy of leafy spurge for public and private lands will emerge from this study.

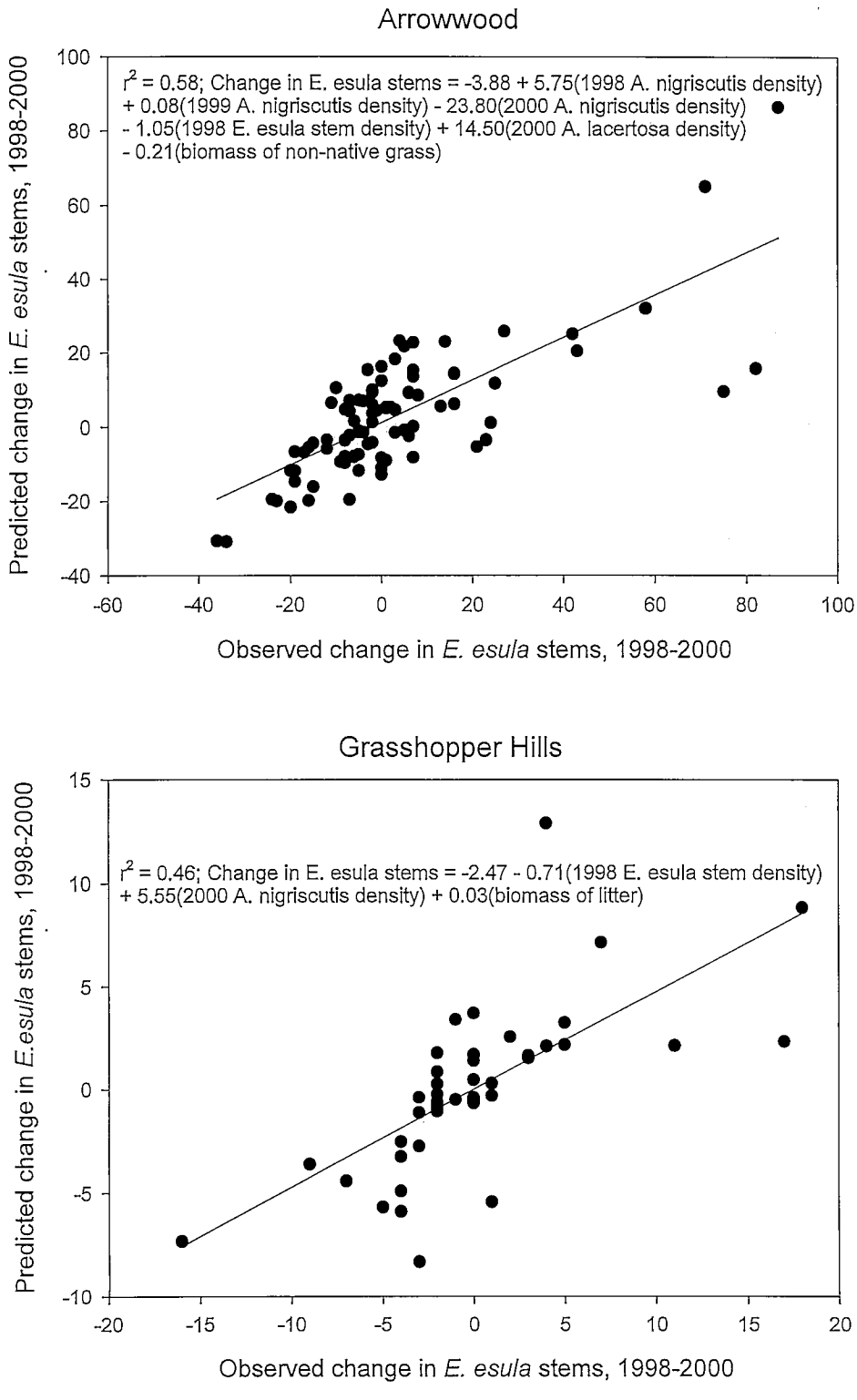


Fig. 5. Predicted versus observed change in *E. esula* stem number between 1998 and 2000 at Arrowwood NWR. Stepwise regression analyses on data from each site were used to determine the variables best able to predict change in *E. esula* stem number between 1998 and 2000, and these figures illustrate the moderate success of the chosen predictor variables

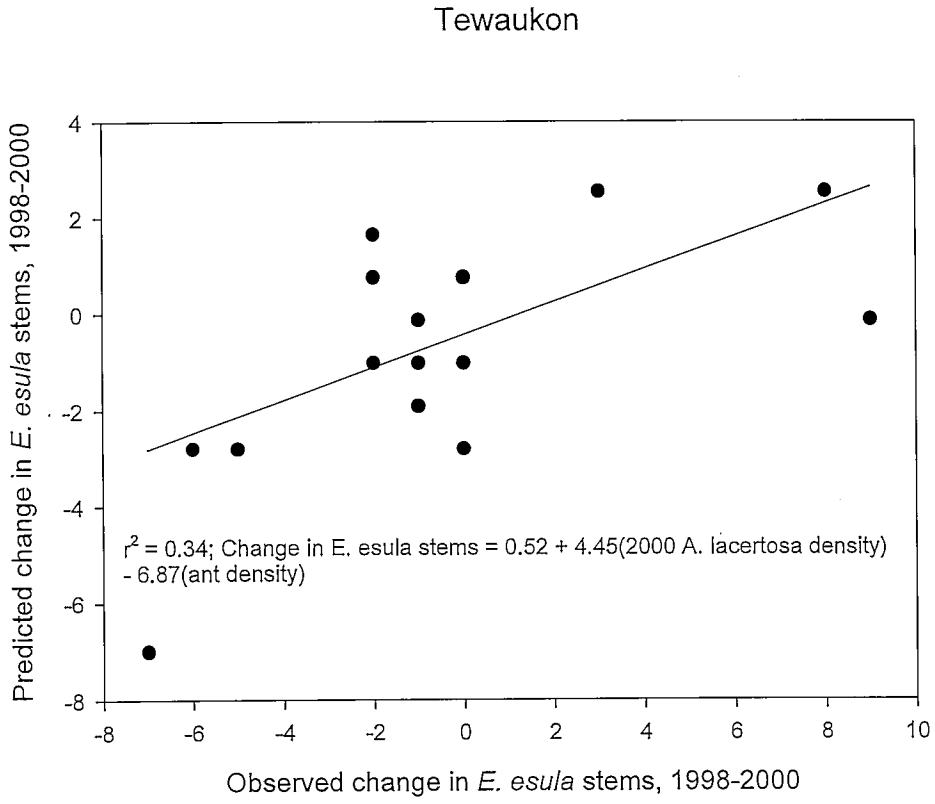


Fig. 6. Predicted versus observed change in *E. esula* stem number between 1998 and 2000 at Tewaukon NWR. Stepwise regression analyses on data from each site were used to determine the variables best able to predict change in *E. esula* stem number between 1998 and 2000, and this figure illustrates the moderate success of the chosen predictor variables

Appendix 1. 2000 Plant species composition of study sites at Arrowwood and Tewaukon NWR ranked by relative frequency (the percentage of plots where a species was present).

Arrowwood 1 (AW1)

Rank	Species code	Genus	Species	Habit	Growth form	Origin	Frequency
1	poapra	*Poa*	*pratensis*	perennial	grass	introduced	100
2	eupesu	*Euphorbia*	*esula*	perennial	forb	introduced	70.97
3	rosark	*Rosa*	*arkansana*	perennial	woody	native	61.29
4	symocc	*Symphoricarpos*	*occidentalis*	perennial	woody	native	58.06
5	broine	*Bromus*	*inermis*	perennial	grass	introduced	51.61
6	ambpsi	*Ambrosia*	*psilostachya*	perennial	forb	native	38.71
7	Artlud	*Artemisia*	*ludoviciana*	perennial	forb	native	35.48
8	callon	*Calamovilfa*	*longifolia*	perennial	grass	native	32.26
9	solcan	*Solidago*	*canadensis*	perennial	forb	native	29.03
10	agrsmi	*Agropyron*	*smithii*	perennial	grass	native	25.81
11	asteri	*Aster*	*ericoides*	perennial	forb	native	19.35
12	ascsyr	*Asclepias*	*syriaca*	perennial	forb	native	19.35
13	lacobl	*Lactuca*	*oblongifolia*	perennial	forb	native	16.13
14	amocan	*Amorpha*	*canescens*	perennial	woody	native	12.90
15	gaucoc	*Gaura*	*coccinea*	perennial	forb	native	12.90
16	liapun	*Liatris*	*punctata*	perennial	forb	native	12.90
17	artdra	*Artemisia*	*dracunculus*	perennial	forb	native	12.90
18	lygjun	*Lygodesmia*	*juncea*	perennial	forb	native	12.90
19	solspp	*Solidago*	*spp.*	perennial	forb	native	12.90
20	sticom	*Stipa*	*comata*	perennial	grass	native	12.90
21	carspp	*Carex*	*spp.*	perennial	sedge	native	9.68
22	agrrep	*Agropyron*	*repens*	perennial	grass	introduced	9.68
23	glylep	*Glycyrrhiza*	*lepidota*	perennial	forb	native	9.68
24	solmol	*Solidago*	*mollis*	perennial	forb	native	9.68
25	helrig	*Helianthus*	*rigidus*	perennial	forb	native	9.68
26	psoarg	*Psoralea*	*argophylla*	perennial	forb	native	9.68
27	vicame	*Vicia*	*americana*	perennial	forb	native	9.68
28	cirarv	*Cirsium*	*arvense*	perennial	forb	introduced	6.45
29	meloff	*Melilotus*	*officinalis*	biennial	forb	introduced	6.45
30	dalpur	*Dalea*	*purpurea*	perennial	forb	native	6.45
31	phyvir	*Physalis*	*virginiana*	perennial	forb	native	6.45
32	artfri	*Artemisia*	*frigida*	perennial	forb	native	6.45
33	boucur	*Bouteloua*	*curtipendula*	perennial	grass	native	6.45
34	stivir	*Stipa*	*viridula*	perennial	grass	native	3.23
35	galbor	*Galium*	*boreale*	perennial	forb	native	3.23
36	spapec	*Spartina*	*pectinata*	perennial	grass	native	3.23
37	ascova	*Asclepias*	*ovalifolia*	perennial	forb	native	3.23
38	bougra	*Bouteloua*	*gracilis*	perennial	grass	native	3.23
39	chrvil	*Chrysopsis*	*villosa*	perennial	forb	native	3.23
40	cirund	*Cirsium*	*undulatum*	perennial	forb	native	3.23
41	echang	*Echinacea*	*angustifolia*	perennial	forb	native	3.23
42	koepyr	*Koeleria*	*pyrimidata*	perennial	grass	native	3.23
43	litinc	*Lithospermum*	*incisum*	perennial	forb	native	3.23
44	poaspp	*Poa*	*spp.*	perennial	forb	uncertain	3.23
45	ratcol	*Ratibida*	*columnifera*	perennial	forb	native	3.23
46	sornut	*Sorghastrum*	*nutans*	perennial	grass	native	3.23
47	taroff	*Taraxacum*	*officinale*	perennial	forb	introduced	3.23
48	thaven	*Thalictrum*	*venulosum*	perennial	forb	native	3.23

Arrowwood 2 (AW2)

Rank	Species code	Genus	Species	Habit	Growth form	Origin	Frequency
1	poapra	*Poa*	*pratensis*	perennial	grass	introduced	84.62
2	eupesu	*Euphorbia*	*esula*	perennial	forb	introduced	69.23
3	symocc	*Symphoricarpos*	*occidentalis*	perennial	woody	native	65.38
4	broine	*Bromus*	*inermis*	perennial	grass	introduced	65.38
5	rosark	*Rosa*	*arkansana*	perennial	woody	native	57.69
6	cirarv	*Cirsium*	*arvense*	perennial	forb	introduced	38.46
7	lacobl	*Lactuca*	*oblongifolia*	perennial	forb	native	23.08
8	agrrep	*Agropyron*	*repens*	perennial	grass	introduced	23.08
9	agrsmi	*Agropyron*	*smithii*	perennial	grass	native	19.23
10	ascsyr	*Asclepias*	*syriaca*	perennial	forb	native	15.38
11	amocan	*Amorpha*	*canescens*	perennial	woody	native	15.38
12	carspp	*Carex*	*spp.*	perennial	sedge	native	15.38
13	galbor	*Galium*	*boreale*	perennial	forb	native	15.38
14	toxryd	*Toxicodendron*	*rydbergii*	perennial	woody	native	15.38
15	artlud	*Artemisia*	*ludoviciana*	perennial	forb	native	11.54
16	asteri	*Aster*	*ericoides*	perennial	forb	native	11.54
17	helrig	*Helianthus*	*rigida*	perennial	forb	native	11.54
18	ulmrub	*Ulmus*	*rubra*	perennial	woody	native	11.54
19	craspp	*Crataegus*	*spp*	perennial	woody	native	11.54
20	solgig	*Solidago*	*giganteum*	perennial	forb	native	11.54
21	urtdio	*Urtica*	*dioica*	perennial	forb	native	11.54
22	callon	*Calamovilfa*	*longifolia*	perennial	grass	native	7.69
23	glylep	*Glycyrrhiza*	*lepidota*	perennial	forb	native	7.69
24	meloff	*Melilotus*	*officinalis*	biennial	forb	introduced	7.69
25	dalpur	*Dalea*	*purpurea*	perennial	forb	native	7.69
26	spapec	*Spartina*	*pectinata*	perennial	grass	native	7.69
27	conarv	*Convolvulus*	*arvensis*	perennial	forb	introduced	7.69
28	pruvir	*Prunus*	*virginiana*	perennial	woody	native	7.69
29	ambpsi	*Ambrosia*	*psilostachya*	perennial	forb	native	3.85
30	gaucoc	*Gaura*	*coccinea*	perennial	forb	native	3.85
31	stivir	*Stipa*	*viridula*	perennial	grass	native	3.85
32	sonarv	*Sonchus*	*arvensis*	perennial	forb	introduced	3.85
33	elecom	*Eleagnus*	*commutata*	perennial	woody	native	3.85
34	apocan	*Apocynum*	*cannabinum*	perennial	forb	native	3.85
35	oxadil	*Oxalis*	*dillenii*	perennial	forb	native	3.85
36	anecan	*Anemone*	*canadensis*	perennial	forb	native	3.85
37	achmil	*Achillea*	*millefolium*	perennial	forb	native	3.85
38	anespp	*Anemone*	*spp.*	perennial	forb	native	3.85
39	arcmin	*Arctium*	*minus*	biennial	forb	native	3.85
40	frapen	*Fraxinus*	*pennsylvanic a*	perennial	woody	native	3.85
41	fravir	*Fragaria*	*virginiana*	perennial	forb	native	3.85
42	melspp	*Melilotus*	*spp.*	biennial	forb	introduced	3.85
43	nepcat	*Nepeta*	*cataria*	perennial	forb	introduced	3.85
44	parqui	*Parthenocissus*	*quinquefolia*	perennial	woody	native	3.85

Arrowwood 3 (AW3)

Rank	Species code	Genus	Species	Habit	Growth form	Origin	Frequency
1	poapra	*Poa*	*pratensis*	perennial	grass	introduced	87.50
2	eupesu	*Euphorbia*	*esula*	perennial	forb	introduced	75.00
3	rosark	*Rosa*	*arkansana*	perennial	woody	native	75.00
4	symocc	*Symphoricarpos*	*occidentalis*	perennial	woody	native	62.50
5	broine	*Bromus*	*inermis*	perennial	grass	introduced	43.75
6	asteri	*Aster*	*ericoides*	perennial	forb	native	43.75
7	carspp	*Carex*	*spp.*	perennial	sedge	native	37.50
8	solmol	*Solidago*	*mollis*	perennial	forb	native	37.50
9	ascsyr	*Asclepias*	*syriaca*	perennial	forb	native	31.25
10	amocan	*Amorpha*	*canescens*	perennial	woody	native	31.25
11	artlud	*Artemisia*	*ludoviciana*	perennial	forb	native	31.25
12	sonarv	*Sonchus*	*arvensis*	perennial	forb	introduced	31.25
13	cirarv	*Cirsium*	*arvense*	perennial	forb	introduced	25.00
14	agrsmi	*Agropyron*	*smithii*	perennial	grass	native	25.00
15	glylep	*Glycyrrhiza*	*lepidota*	perennial	forb	native	25.00
16	stivir	*Stipa*	*viridula*	perennial	grass	native	25.00
17	ulmrub	*Ulmus*	*rubra*	perennial	woody	native	18.75
18	ambpsi	*Ambrosia*	*psilostachya*	perennial	forb	native	18.75
19	artabs	*Artemisia*	*absinthium*	perennial	forb	introduced	18.75
20	callon	*Calamovilfa*	*longifolia*	perennial	grass	native	12.50
21	solmis	*Solidago*	*missouriensis*	perennial	forb	native	12.50
22	lacobl	*Lactuca*	*oblongifolia*	perennial	forb	native	6.25
23	agrrep	*Agropyron*	*repens*	perennial	grass	introduced	6.25
24	spapec	*Spartina*	*pectinata*	perennial	grass	native	6.25
25	conarv	*Convolvulus*	*arvensis*	perennial	forb	introduced	6.25
26	gaucoc	*Gaura*	*coccinea*	perennial	forb	native	6.25
27	anecan	*Anemone*	*canadensis*	perennial	forb	native	6.25
28	solspp	*Solidago*	*spp.*	perennial	forb	native	6.25
29	psoarg	*Psoralea*	*argophylla*	perennial	forb	native	6.25
30	vicame	*Vicia*	*americana*	perennial	forb	native	6.25
31	ascova	*Asclepias*	*ovalifolia*	perennial	forb	native	6.25
32	chrvil	*Chrysopsis*	*villosa*	perennial	forb	native	6.25
33	onomol	*Onosmodium*	*molle*	perennial	forb	native	6.25
34	astfle	*Astragalus*	*flexuosus*	perennial	forb	native	6.25
35	junspp	*Juncus*	*spp*	perennial	rush	native	6.25
36	kuheup	*Kuhnia*	*eupatorioides*	perennial	forb	native	6.25
37	tradub	*Tragopogon*	*dubius*	biennial	forb	introduced	6.25

Arrowwood 4 (AW4)

Rank	Species codes	Genus	Species	Habit	Growth form	Origin	Frequency
1	poapra	*Poa*	*pratensis*	perennial	grass	introduced	100.0
2	eupesu	*Euphorbia*	*esula*	perennial	forb	introduced	87.5
3	broine	*Bromus*	*inermis*	perennial	grass	introduced	52.5
4	symocc	*Symphoricarpos*	*occidentalis*	perennial	woody	native	50.0
5	rosark	*Rosa*	*arkansana*	perennial	woody	native	40.0
6	carspp	*Carex*	*spp.*	perennial	sedge	native	32.5
7	asteri	*Aster*	*ericoides*	perennial	forb	native	27.5
8	ascsyr	*Asclepias*	*syriaca*	perennial	forb	native	20.0
9	agrrep	*Agropyron*	*repens*	perennial	grass	introduced	20.0
10	artlud	*Artemisia*	*ludoviciana*	perennial	forb	native	17.5
11	cirarv	*Cirsium*	*arvense*	perennial	forb	introduced	17.5
12	elecom	*Eleagnus*	*commutata*	perennial	woody	native	17.5
13	agrsmi	*Agropyron*	*smithii*	perennial	grass	native	12.5
14	amocan	*Amorpha*	*canescens*	perennial	woody	native	10.0
15	stivir	*Stipa*	*viridula*	perennial	grass	native	10.0
16	ambpsi	*Ambrosia*	*psilostachya*	perennial	forb	native	10.0
17	gaucoc	*Gaura*	*coccinea*	perennial	forb	native	10.0
18	solmol	*Solidago*	*mollis*	perennial	forb	native	7.5
19	sonarv	*Sonchus*	*arvensis*	perennial	forb	introduced	7.5
20	glylep	*Glycyrrhiza*	*lepidota*	perennial	forb	native	7.5
21	solmis	*Solidago*	*missouriensis*	perennial	forb	native	7.5
22	liapun	*Liatris*	*punctata*	perennial	forb	native	7.5
23	ulmrub	*Ulmus*	*rubra*	perennial	woody	native	5.0
24	artabs	*Artemisia*	*absinthium*	perennial	forb	introduced	5.0
25	callon	*Calamovilfa*	*longifolia*	perennial	grass	native	5.0
26	lacobl	*Lactuca*	*oblongifolia*	perennial	forb	native	5.0
27	psoarg	*Psoralea*	*argophylla*	perennial	forb	native	5.0
28	meloff	*Melilotus*	*officinalis*	biennial	forb	introduced	5.0
29	apocan	*Apocynum*	*cannabinum*	perennial	forb	native	5.0
30	oxadil	*Oxalis*	*dillenii*	perennial	forb	native	5.0
31	anecyl	*Anemone*	*cylindrica*	perennial	forb	native	5.0
32	vicame	*Vicia*	*americana*	perennial	forb	native	2.5
33	ascova	*Asclepias*	*ovalifolia*	perennial	forb	native	2.5
34	onomol	*Onosmodium*	*molle*	perennial	forb	native	2.5
35	helrig	*Helianthus*	*rigida*	perennial	forb	native	2.5
36	dalpur	*Dalea*	*purpurea*	perennial	forb	native	2.5
37	pruvir	*Prunus*	*virginiana*	perennial	woody	native	2.5
38	artdra	*Artemisia*	*dracunculus*	perennial	forb	native	2.5
39	lygjun	*Lygodesmia*	*juncea*	perennial	forb	native	2.5
40	phyvir	*Physalis*	*virginiana*	perennial	forb	native	2.5
41	bougra	*Bouteloua*	*gracilis*	perennial	grass	native	2.5
42	allste	*Allium*	*stellatum*	perennial	forb	native	2.5
43	ambspp	*Ambrosia*	*spp.*	uncertain	forb	native	2.5
44	ascspp	*Asclepias*	*syriaca*	perennial	forb	native	2.5
45	dicspp	*Dicanthelium*	*spp.*	perennial	grass	native	2.5
46	lycasp	*Lycopus*	*asper*	perennial	forb	native	2.5
47	polver	*Polygala*	*verticillata*	annual	forb	native	2.5

Grasshopper Hills 1 (GH1)

Rank	Species codes	Genus	Species	Habit	Growth form	Origin	Frequency
1	poapra	*Poa*	*pratensis*	perennial	grass	introduced	83.3
2	eupesu	*Euphorbia*	*esula*	perennial	forb	introduced	60.0
3	carspp	*Carex*	*spp.*	perennial	sedge	native	50.0
4	artlud	*Artemisia*	*ludoviciana*	perennial	forb	native	43.3
5	symocc	*Symphoricarpos*	*occidentalis*	perennial	woody	native	43.3
6	stivir	*Stipa*	*viridula*	perennial	grass	native	36.7
7	asteri	*Aster*	*ericoides*	perennial	forb	native	33.3
8	agrcri	*Agropyron*	*cristatum*	perennial	grass	introduced	23.3
9	agrsmi	*Agropyron*	*smithii*	perennial	grass	native	23.3
10	amocan	*Amorpha*	*canescens*	perennial	woody	native	23.3
11	bougra	*Bouteloua*	*gracilis*	perennial	grass	native	23.3
12	meloff	*Melilotus*	*officinalis*	biennial	forb	introduced	23.3
13	rosark	*Rosa*	*arkansana*	perennial	woody	native	23.3
14	sticom	*Stipa*	*comata*	perennial	grass	native	23.3
15	agrcan	*Agropyron*	*caninum*	perennial	grass	native	20.0
16	artdra	*Artemisia*	*dracunculus*	perennial	forb	native	20.0
17	artfri	*Artemisia*	*frigida*	perennial	forb	native	16.7
18	broine	*Bromus*	*inermis*	perennial	grass	introduced	16.7
19	dalpur	*Dalea*	*purpurea*	perennial	forb	native	16.7
20	gaucoc	*Gaura*	*coccinea*	perennial	forb	native	16.7
21	liapun	*Liatris*	*punctata*	perennial	forb	native	16.7
22	cirarv	*Cirsium*	*arvense*	perennial	forb	introduced	13.3
23	tradub	*Tragopogon*	*dubius*	biennial	forb	introduced	13.3
24	agrrep	*Agropyron*	*repens*	perennial	grass	introduced	10.0
25	ambpsi	*Ambrosia*	*psilostachya*	perennial	forb	native	10.0
26	chrvil	*Chrysopsis*	*villosa*	perennial	forb	native	10.0
27	lacobl	*Lactuca*	*oblongifolia*	perennial	forb	native	10.0
28	solcan	*Solidago*	*canadensis*	perennial	forb	native	10.0
29	solmol	*Solidago*	*mollis*	perennial	forb	native	10.0
30	amespp.	*Amelanchier*	*spp.*	perennial	woody	native	6.7
31	boucur	*Bouteloua*	*curtipendula*	perennial	grass	native	6.7
32	callon	*Calamovilfa*	*longifolia*	perennial	grass	native	6.7
33	echpur	*Echinacea*	*purpurea*	perennial	forb	native	6.7
34	equlae	*Equisetum*	*laevigatum*	annual	forb	native	6.7
35	glylep	*Glycyrrhiza*	*lepidota*	perennial	forb	native	6.7
36	psoarg	*Psoralea*	*argophylla*	perennial	forb	native	6.7
37	solmis	*Solidago*	*missouriensis*	perennial	forb	native	6.7
38	stispa	*Stipa*	*spartea*	perennial	grass	native	6.7
39	anecan	*Anemone*	*canadensis*	perennial	forb	native	3.3
40	anespp	*Anemone*	*spp.*	perennial	forb	native	3.3
41	cerarv	*Cerastium*	*arvense*	perennial	forb	native	3.3
42	eupspp.	*Euphorbia*	*spp.*	annual	forb	native	3.3
43	conarv	*Convolvulus*	*arvensis*	perennial	forb	introduced	3.3
44	echang	*Echinacea*	*angustifolia*	perennial	forb	native	3.3
45	galbor	*Galium*	*boreale*	perennial	forb	native	3.3
46	junbal	*Juncus*	*balticus*	perennial or rarely annual	rush	native	3.3
47	lygjun	*Lygodesmia*	*juncea*	perennial	forb	native	3.3
48	muhcus	*Muhlenbergia*	*cuspidata*	perennial	grass	native	3.3
49	solspp	*Solidago*	*spp.*	perennial	forb	native	3.3
50	urtdio	*Urtica*	*dioica*	perennial	forb	native	3.3
51	vicame	*Vicia*	*americana*	perennial	forb	native	3.3

Grasshopper Hills 2 (GH2)

Rank	Species codes	Genus	Species	Habit	Growth form	Origin	Frequency
1	poapra	*Poa*	*pratensis*	perennial	grass	introduced	100.0
2	symocc	*Symphoricarpos*	*occidentalis*	perennial	woody	native	75.6
3	eupesu	*Euphorbia*	*esula*	perennial	forb	introduced	57.8
4	rosark	*Rosa*	*arkansana*	perennial	woody	native	44.4
5	asteri	*Aster*	*ericoides*	perennial	forb	native	35.6
6	artlud	*Artemisia*	*ludoviciana*	perennial	forb	native	33.3
7	stivir	*Stipa*	*viridula*	perennial	grass	native	28.9
8	carspp	*Carex*	*spp.*	perennial	sedge	native	24.4
9	broine	*Bromus*	*inermis*	perennial	grass	introduced	24.4
10	cirarv	*Cirsium*	*arvense*	perennial	forb	introduced	22.2
11	meloff	*Melilotus*	*officinalis*	biennial	forb	introduced	20.0
12	agrsmi	*Agropyron*	*smithii*	perennial	grass	native	17.8
13	agrrep	*Agropyron*	*repens*	perennial	grass	introduced	17.8
14	amocan	*Amorpha*	*canescens*	perennial	woody	native	13.3
15	artdra	*Artemisia*	*dracunculus*	perennial	forb	native	13.3
16	ambpsi	*Ambrosia*	*psilostachya*	perennial	forb	native	13.3
17	galbor	*Galium*	*boreale*	perennial	forb	native	13.3
18	agrcan	*Agropyron*	*caninum*	perennial	grass	native	11.1
19	chrvil	*Chrysopsis*	*villosa*	perennial	forb	native	11.1
20	psoarg	*Psoralea*	*argophylla*	perennial	forb	native	8.9
21	ascsyr	*Asclepias*	*syriaca*	perennial	forb	native	8.9
22	artfri	*Artemisia*	*frigida*	perennial	forb	native	6.7
23	dalpur	*Dalea*	*purpurea*	perennial	forb	native	6.7
24	solmol	*Solidago*	*mollis*	perennial	forb	native	6.7
25	callon	*Calamovilfa*	*longifolia*	perennial	grass	native	6.7
26	helrig	*Helianthus*	*rigidus*	perennial	forb	native	6.7
27	sticom	*Stipa*	*comata*	perennial	grass	native	4.4
28	solmis	*Solidago*	*missouriensis*	perennial	forb	native	4.4
29	pruvir	*Prunus*	*virginiana*	perennial	woody	native	4.4
30	bougra	*Bouteloua*	*gracilis*	perennial	grass	native	2.2
31	conarv	*Convolvulus*	*arvensis*	perennial	forb	introduced	2.2
32	andger	*Andropogon*	*gerardii*	perennial	grass	native	2.2
33	anepat	*Anemone*	*patens*	perennial	forb	native	2.2
34	astfle	*Astragalus*	*flexuosus*	perennial	forb	native	2.2
35	carele	*Carex*	*eleocharis*	perennial	forb	native	2.2
36	cirund	*Cirsium*	*undulatum*	perennial	forb	native	2.2
37	craspp	*Crataegus*	*spp*	perennial	woody	native	2.2
38	fravir	*Fragaria*	*virginiana*	perennial	forb	native	2.2
39	heuric	*Heuchera*	*richardsonii*	perennial	forb	native	2.2
40	onomol	*Onosmodium*	*molle*	perennial	forb	native	2.2

Tewaukon 1 (TE1)

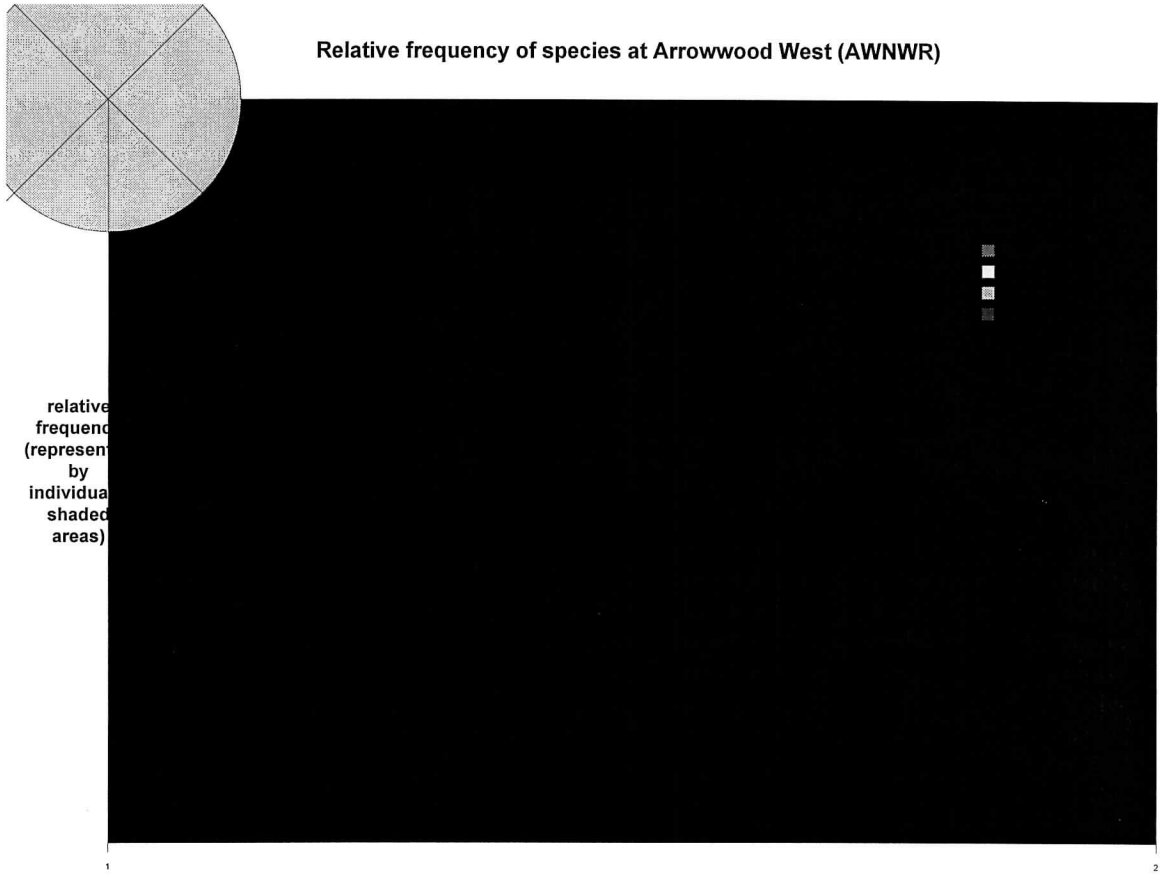
Rank	Species codes	Genus	Species	Habit	Growth form	Origin	Frequency
1	poapra	*Poa*	*pratensis*	perennial	grass	introduced	100.0
2	agrrep	*Agropyron*	*repens*	perennial	grass	introduced	55.6
3	callon	*Calamovilfa*	*longifolia*	perennial	grass	native	55.6
4	artlud	*Artemisia*	*ludoviciana*	perennial	forb	native	44.4
5	stispp	*Stipa*	*spp.*	perennial	grass	native	44.4
6	ambpsi	*Ambrosia*	*psilostachya*	perennial	forb	native	33.3
7	bougra	*Bouteloua*	*gracilis*	perennial	grass	native	33.3
8	carspp	*Carex*	*spp.*	perennial	sedge	native	22.2
9	equlae	*Equisetum*	*laevigatum*	annual	forb	native	22.2
10	phyvir	*Physalis*	*virginiana*	perennial	forb	native	22.2
11	agrsmi	*Agropyron*	*smithii*	perennial	grass	native	11.1
12	andger	*Andropogon*	*gerardii*	perennial	grass	native	11.1
13	dicspp	*Dicanthelium*	*spp.*	perennial	grass	native	11.1
14	eupesu	*Euphorbia*	*esula*	perennial	forb	introduced	11.1
15	lotpur	*Lotus*	*purshianus*	annual	forb	native	11.1
16	meloff	*Melilotus*	*officinalis*	biennial	forb	introduced	11.1
17	muhrac	*Muhlenbergia*	*racemosa*	perennial	grass	native	11.1
18	panvir	*Panicum*	*virgatum*	perennial	grass	native	11.1
19	solmis	*Solidago*	*missouriensis*	perennial	forb	native	11.1

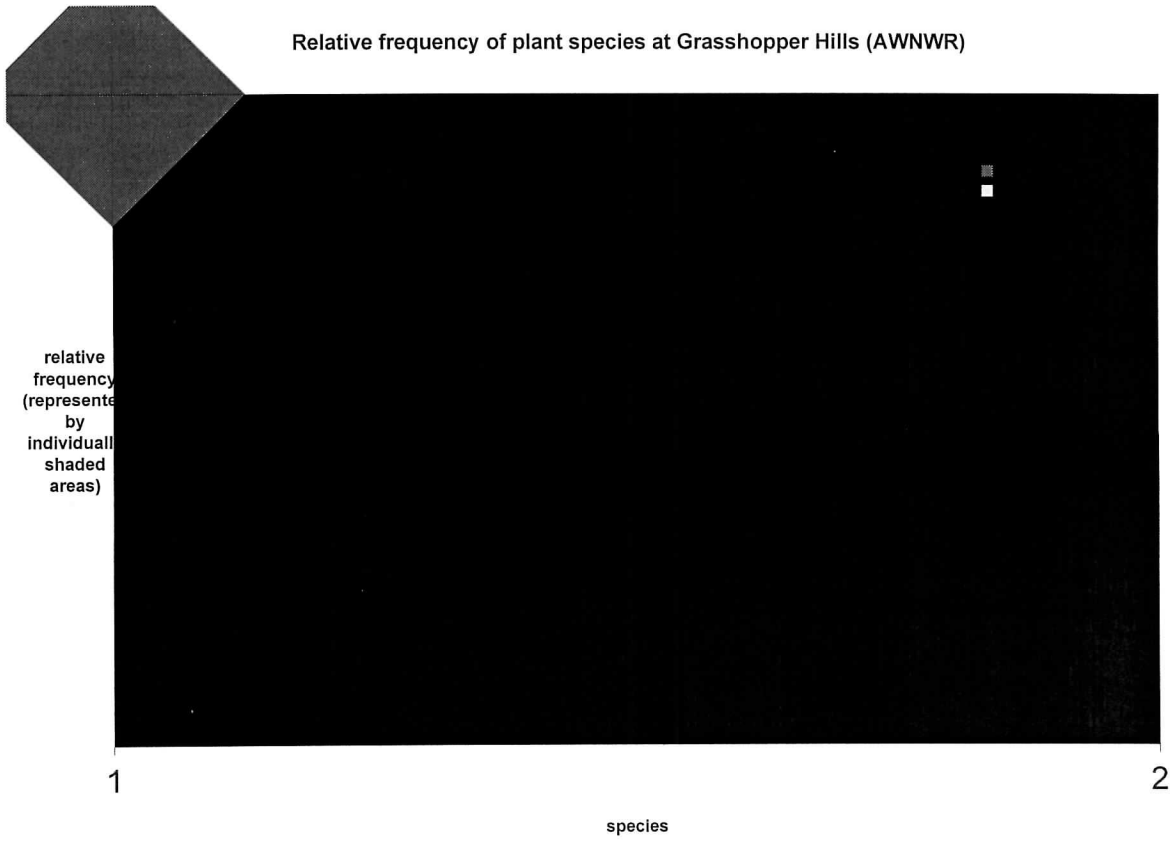
Tewaukon 2 (TE2)

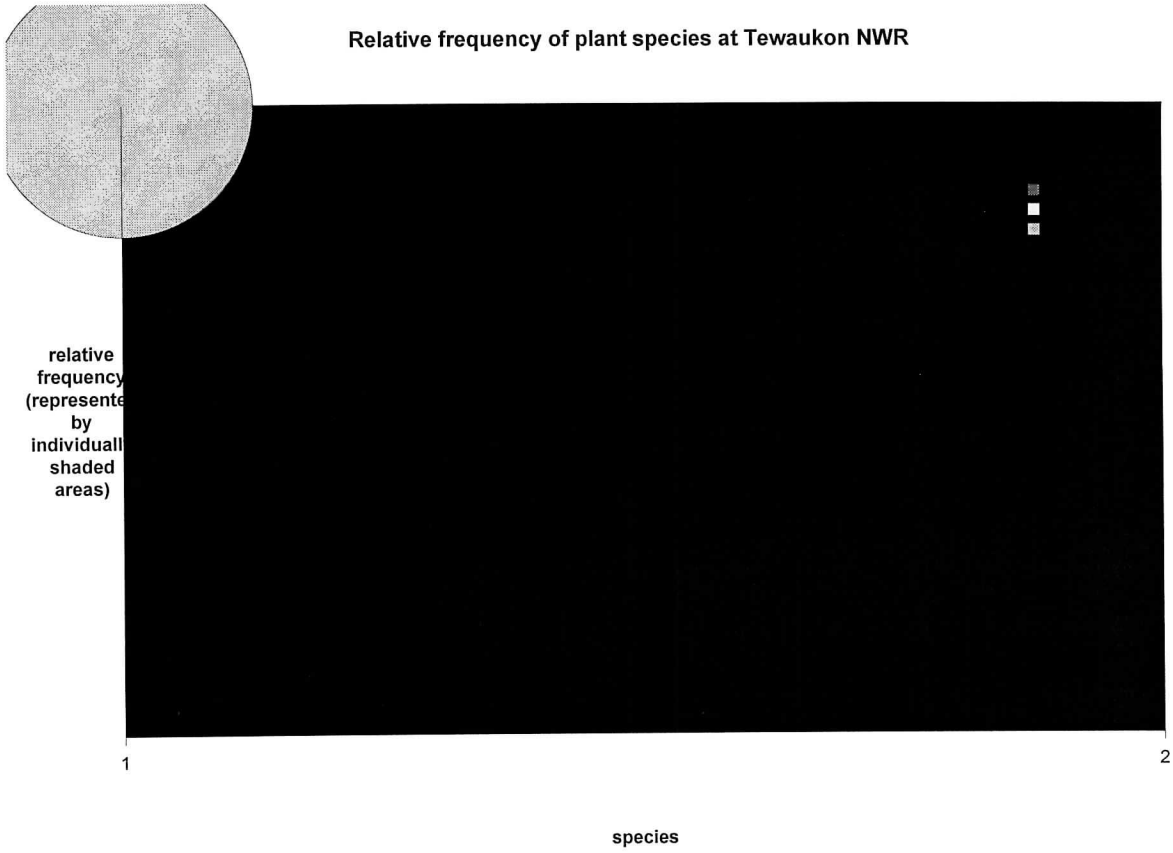
Rank	Species codes	Genus	Species	Habit	Growth form	Origin	Frequency
1	poapra	*Poa*	*pratensis*	perennial	grass	introduced	100.0
2	carspp	*Carex*	*spp.*	perennial	sedge	native	72.7
3	equlae	*Equisetum*	*laevigatum*	annual	forb	native	59.1
4	ambpsi	*Ambrosia*	*psilostachya*	perennial	forb	native	45.5
5	asteri	*Aster*	*ericoides*	perennial	forb	native	40.9
6	eupesu	*Euphorbia*	*esula*	perennial	forb	introduced	40.9
7	agrrep	*Agropyron*	*repens*	perennial	grass	introduced	36.4
8	artlud	*Artemisia*	*ludoviciana*	perennial	forb	native	36.4
9	solmis	*Solidago*	*missouriensis*	perennial	forb	native	18.2
10	stispa	*Stipa*	*spartea*	perennial	grass	native	18.2
11	broine	*Bromus*	*inermis*	perennial	grass	introduced	13.6
12	dicspp	*Dicanthelium*	*spp.*	perennial	grass	native	13.6
13	agrsmi	*Agropyron*	*smithii*	perennial	grass	native	9.1
14	callon	*Calamovilfa*	*longifolia*	perennial	grass	native	9.1
15	panvir	*Panicum*	*virgatum*	perennial	grass	native	9.1
16	solcan	*Solidago*	*canadensis*	perennial	forb	native	9.1
17	andger	*Andropogon*	*gerardii*	perennial	grass	native	4.5
18	ascspe	*Asclepias*	*speciosa*	perennial	forb	native	4.5
19	lacobl	*Lactuca*	*oblongifolia*	perennial	forb	native	4.5
20	meloff	*Melilotus*	*officinalis*	biennial	forb	introduced	4.5
21	phyvir	*Physalis*	*virginiana*	perennial	forb	native	4.5
22	spocry	*Sporobolus*	*cryptandrus*	perennial	grass	native	4.5
23	ulmspp	*Ulmus*	*spp.*	perennial	woody	native	4.5

Tewaukon 3 (TE3)

Rank	Species codes	Genus	Species	Habit	Growth form	Origin	Frequency
1	poapra	*Poa*	*pratensis*	perennial	grass	introduced	100.0
2	agrrep	*Agropyron*	*repens*	perennial	grass	introduced	62.1
3	asteri	*Aster*	*ericoides*	perennial	forb	native	62.1
4	carspp	*Carex*	*spp.*	perennial	sedge	native	51.7
5	eupesu	*Euphorbia*	*esula*	perennial	forb	introduced	48.3
6	equlae	*Equisetum*	*laevigatum*	annual	forb	native	44.8
7	ambpsi	*Ambrosia*	*psilostachya*	perennial	forb	native	41.4
8	artlud	*Artemisia*	*ludoviciana*	perennial	forb	native	41.4
9	broine	*Bromus*	*inermis*	perennial	grass	introduced	37.9
10	solcan	*Solidago*	*canadensis*	perennial	forb	native	34.5
11	callon	*Calamovilfa*	*longifolia*	perennial	grass	native	17.2
12	solmis	*Solidago*	*missouriensis*	perennial	forb	native	17.2
13	junbal	*Juncus*	*balticus*	perennial	forb	native	13.8
14	meloff	*Melilotus*	*officinalis*	biennial	forb	introduced	13.8
15	andger	*Andropogon*	*gerardii*	perennial	grass	native	10.3
16	sticom	*Stipa*	*comata*	perennial	grass	native	10.3
17	cirarv	*Cirsium*	*arvense*	perennial	forb	introduced	6.9
18	cirund	*Cirsium*	*undulatum*	perennial	forb	native	6.9
19	junspp	*Juncus*	*spp.*	perennial	rush	native	6.9
20	panvir	*Panicum*	*virgatum*	perennial	grass	native	6.9
21	setver	*Setaria*	*verticillata*	annual	grass	introduced	6.9
22	achmil	*Achillea*	*millefolium*	perennial	forb	native	3.4
23	agrsto	*Agrostis*	*stolonifera*	perennial	grass	native	3.4
24	ascspp	*Asclepias*	*spp.*	perennial	forb	native	3.4
25	ascsyr	*Asclepias*	*syriaca*	perennial	forb	native	3.4
26	astspp	*Aster*	*spp.*	perennial	forb	native	3.4
27	dicspp	*Dicanthelium*	*spp.*	perennial	grass	native	3.4
28	glylep	*Glycyrrhiza*	*lepidota*	perennial	forb	native	3.4
29	phaaru	*Phalaris*	*arundinacea*	perennial	grass	native	3.4
30	rosark	*Rosa*	*arkansana*	perennial	woody	native	3.4
31	solspp	*Solidago*	*spp.*	perennial	forb	native	3.4


Relative frequency of species at Arrowwood West (AWNWR)
relative frequenc (represen by individua shaded areas)
1
2
species


Relative frequency of plant species at Grasshopper Hills (AWNWR)
relative frequency (represente by individuall shaded areas)
1
2
species


Relative frequency of plant species at Tewaukon NWR
relative frequency (represente by individuall shaded areas)
1
2
species